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Influence of Varied Nitrogen Quantities on the Growth, Harvest Index, and Economic Viability of Barley

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ABSTRACT: Farmers in the Indian state of Haryana widely cultivate barley (*Hordeum vulgare* L.) due to its popularity. Nitrogen (N) is an essential element for plant growth and development. In areas where soil nitrogen is limited, the yield of barley is dependent on the amount of N fertilizer applied. Therefore, determining the optimal amount of N fertilizer is crucial for achieving profitable barley cultivation. During the winter season of 2019-2020, research was carried out at the research farm of the School of Agricultural Sciences (SoAS), Gurugram, Haryana. The study was conducted using a randomized complete block design (RCBD) with six N levels (0, 30, 45, 60, 75, and 90 kgha^{-1}) and four replications. The growth parameters and harvest index (HI) of the barley crop were documented, and an economic analysis was performed to determine the net return and benefit-to-cost (B:C) ratio of the crop. Ensuring consistent environmental conditions throughout the crop growth phase posed a challenge for this study. The plots that received 60 kg N ha^{-1} had the highest growth parameters and HI. However, the plots that were treated with 90 kg N ha^{-1} had the highest net return and B:C ratio compared to other treatments. Therefore, it is recommended that barley crop growers use this dosage for better profitability. These findings can be useful for barley farmers and policymakers in making informed decisions on N application for optimal crop growth and economic benefits. Additional research can be conducted over an extended period to investigate various parameters of the barley crop.

Keywords: Barley, Nitrogen, Crop yield, Growth parameters, Harvest index and Economics.

INTRODUCTION

The evolution of the barley crop during domestication has caused a considerable shift in its primary use, from being a food grain to becoming a feed and malting grain (Pourkheirandish and Komatsuda 2007; Baikl and Ullrich 2008). Barley is the fourth most-produced cereal grain in the world, covering an area of 7 million hectares, with an annual production of 147.4 Mt and a productivity of 3.13 t ha^{-1} (FAO, 2019). In India, barley is commonly known as Jau and is grown over an area of 0.6 million hectares with a production of 1.78 Mt and a productivity of 2.69 tha^{-1} (FAO, 2019). India ranks seventh in the world in terms of both total area and production of barley. Among *rabi* cereals in India, barley ranks second to wheat in terms of acreage and production. It is predominantly grown in the northern plains of India, including Uttar Pradesh, Rajasthan, Madhya Pradesh, Bihar, Haryana, and Punjab. In Haryana, barley is grown on approximately 35,000 hectares of land, with a production of 0.12 Mt and a productivity of 3.42 tha^{-1}.

Ensuring sufficient mineral fertilization is crucial for the prosperous growth of any crop, and a lack of N is a significant factor affecting barley production. According to Zebarth *et al.* (2009), N is considered the most limiting factor in the growth of non-legume crops, and it is also generally deficient in most Indian soils. It plays a crucial role in the formation of chlorophyll (Kanwar, 1976) and photosynthesis, as well as in the growth and development of leaves, stems, and the overall yield of the crop. According to Ottman (2009), a limited amount of N can significantly impact crop growth and potentially result in a significant reduction in grain yield. The appropriate amount of N application is determined based on the discrepancy between the crop's demand and the supply of soil N available from organic matter mineralisation and residual N from prior applications. The crop's growth rate and morphology are heavily influenced by N, as noted by Amanullah *et al.* (2009). To achieve optimal yields, cereals require a substantial amount of absorbed N during their growth period. A suitable N dosage can boost leaf area, tiller formation, leaf area index, and leaf area duration, resulting in increased dry matter production and grain yield.

To achieve both maximum production and desirable protein content in grain, N fertilization strategies must be carefully calibrated. Increasing the N rate is essential for crop production since yield and protein content in barley seeds rise with the application of more N, as noted by the references. Quality is also important for crop yield and is influenced primarily by fertilizer levels and application timing. Optimal N fertilization is crucial for obtaining a successful, high-yielding barley crop. On soils with low available N, moderate N rates often result in increased yields. Therefore, there is a pressing need to re-examine the nutrient requirements, particularly for N, to overcome the limitations to higher barley crop productivity. The effect of varied N quantities on the economic viability of barley production has not been extensively studied in Haryana state of India. The limited research available focuses on the relationship between different N levels and the cost-effectiveness of barley production, as well as the potential trade-offs between yield, quality, and economic viability. Further research is needed to explore these aspects and inform optimal N management strategies to improve the overall sustainability of barley farming. With these considerations in mind, an experiment was conducted to investigate the impact of various levels of N doses on the growth, harvest index (HI), and economic aspects of the barley crop.

MATERIALS AND METHODS

In the winter season of 2019-2020, an experiment was conducted at the research farm of SoAS, GDGU, Sohna, Gurugram, Haryana, located at 28°15'44.1" N latitude and 77°03'53.0" E longitude, with an elevation of 211 meters above mean sea level. The climate of Sohna is semi-arid and sub-tropical, with an average annual rainfall of 400 mm. During all stages of crop growth, the monthly mean maximum and minimum temperatures ranged from 16.0°C to 28.9°C and 3.0°C to 13.4°C, respectively. The experimental sandy loam soil was analysed for various soil parameters using three composite soil samples collected from the site. The soil had a pH of 7.95 (alkaline), EC of 0.78 dSm^{-1} (non-saline), 0.40% organic carbon (low), 85.65 kg available N/ha (low), 112.7 kg available K/ha (low), and 11.03 kg available P/ha (medium). The experiment was arranged in a randomized complete block design (RCBD) with six treatments and four replications, with each treatment plot measuring 4 × 5 square metres. The treatments were T_1 (Control), T_2 (30 kg N ha^{-1}), T_3 (45 kg N ha^{-1}), T_4 (60 kg N ha^{-1}), T_5 (75 kg N ha^{-1}) and T_6 (90 kg N ha^{-1}). The treatments received fertilizers through urea, DAP, and MOP, as per the recommendation. The Barley crop variety (PL-426) was sown on November 8, 2019, and harvested on March 13, 2020. The crops were given the recommended dose of phosphorus (30 kg P ha^{-1}), potassium (20 kg K ha^{-1}), and one-third of the required N in the form of basal fertilizer. The remaining two-third part of the N fertilizer was applied through top-dressing based on the different treatments. Growth parameters such as plant height, number of tillers, chlorophyll content, and dry matter accumulation (DMA) were measured on different days after sowing (DAS), and the HI of the various treatments was also recorded. The HI was calculated by the following formula: HI = [(Economical yield / Biological yield) × 100]. To calculate the net return and B:C ratio, an economic analysis was conducted. The data were statistically analysed using analysis of variance (ANOVA) as applicable to RCBD (Gomez and Gomez 1984), and the F test was used to determine the significance of the treatment effects. The standard error of the mean (SEm) was also calculated, and the difference between the means was estimated using critical difference (CD) at a 5% probability level.

RESULTS AND DISCUSSION

Growth parameters. Upon critical analysis of Table 1, it was found that plant height increased with the age of the crop in all treatments. At 30 DAS, both the control treatment (28.94 cm) and the 30 kg N ha^{-1} treatment (30.98 cm) showed significantly lower plant height. Plots receiving 30 kg N/ha and the control treatment without N application were statistically similar. A significantly higher plant height was observed in the plot receiving 60 kg N ha^{-1} (40.41 cm), which was statistically similar to the plot receiving 75 kg N ha^{-1} (37.09 cm). At 60 DAS, the plant height in the 45 kg N ha^{-1} treatment (62.80 cm) was statistically similar to the 60 kg N ha^{-1} treatment (66.20 cm), while the control treatment recorded significantly lower plant height (50.70 cm). At 90 DAS, the plots receiving 45, 75, and 90 kg N ha^{-1} were statistically similar to the plot receiving 60 kg N ha^{-1}, while the control treatment (87.34 cm) and the 30 kg N ha^{-1} treatment (89.69 cm) recorded significantly lower plant height. The increment of plant height with the increase in N levels promotes vegetative growth, more N uptake, increased protein synthesis, cell division, and cell elongation processes (Awasthi and Bhan 1994; Paramjit *et al*., 2001; Satyajeet *et al*., 2003; Pervez *et al*., 2009; Laghari *et al*., 2010). In their study on barley, Shafi *et al*. (2011) found maximum plant height at 60 kg N ha^{-1} followed by 45 kg N ha^{-1}.

The data from Table 1 shows that the number of tillers per meter row length increased with increasing N levels at both 60 and 90 DAS. Among the N levels, the plot receiving 60 kg N/ha had the highest number of tillers (84.50) per meter row length at 90 DAS, which was significantly higher than the control treatment (51.00). The increase in tillers in barley could be attributed to the balanced supply of plant nutrients during the growing season, which created favourable conditions for crop growth. The maximum number of tillers at 90 DAS was also recorded by Yadav *et al.* (2020) in different barley cultivars grown under sodic soils. Berkesia *et al.* (2018) observed significantly maximum effective tillers/m^2 in barley crop receiving 60 kg N/ha over 90 kg N/ha treatment. Similar findings were reported by Malik (2017), who found that the application of 60 kg N ha^{-1} resulted in a significantly higher number of tillers per meter row length compared to plots receiving 30, 45, and 75 kg N ha^{-1}. The usage of N fertilizer at an optimum dose helped in cell division and cell elongation processes, resulting in more lateral tillers (Achera, 2004; Devaraja and Hegde 2006; Laghari *et al*., 2010; Hadi *et al*., 2012).

Table 2 presents the data on chlorophyll content during different stages of crop growth. The chlorophyll content increased as the N levels increased up to 60 kg N ha^{-1}, but then decreased as the N levels increased further. Among the various N levels, the plot receiving 60 kg N ha^{-1} recorded significantly higher chlorophyll content at all stages (30, 60, and 90 DAS) of crop growth, while the plot receiving 75 kg N ha^{-1} was statistically similar to the 60 kg N ha^{-1} treatment. The control plot had significantly lower chlorophyll content at all stages of crop growth. The quantification of chlorophylls is crucial in determining the concentration of pigments involved in light absorption and energy conversion during the photochemical process of photosynthesis. These findings were consistent with those of Kumpawat (2009). Similarly, Hadi *et al.* (2012) reported that dual-purpose barley crops showed the highest chlorophyll content at 60 kg N/ha compared to 40 and 80 kg N ha^{-1}.

Regardless of the treatments applied, there was a consistent increase in DMA as the crop grew (Table 2). Dry matter increased with the increase in N application from the control to the 60 kg N/ha treatments but decreased with further N application (75 and 90 kg N ha^{-1}). At all stages of crop growth, treatment with 60 kg N ha^{-1} had significantly higher DMA than other treatments. At 30 DAS, the 75 kg N ha^{-1} treatment was statistically similar to the 60 kg N ha^{-1} treatment, while the control had significantly lower DMA. At 60 DAS, the control had significantly lower DMA than other treatments. At 90 DAS, the 45 kg N ha^{-1} treatment was statistically similar to the 60 kg N ha^{-1} treatment, while the control had significantly lower DMA. Monitoring the dry matter content is a reliable indicator of proper crop growth and development, and crop yield depends on DMA and partitioning into different plant parts, which increases throughout crop growth. In barley, DMA increased with an increase in N level up to 60 kg N ha^{-1}. Similar results were also reported by Satyajeet *et al.* (2003); Alam and Haider (2006); Kumpawat (2009); Singh *et al.* (2010); Singh *et al.* (2013). Kumawat (2003) also found that barley responded positively to graded doses of N up to 60 kg ha^{-1} in terms of DMA.

Harvest Index and Economics. Table 3 presents data on the harvest index (HI) of barley crops with different levels of N application. Treatment with 60 kg N ha^{-1} resulted in significantly higher HI (34.36%) than the control and treatments with lower doses of N (30 and 45 kg N ha^{-1}). However, all three higher doses of N application (60, 75 & 90 kg N ha^{-1}) were statistically similar in terms of HI. The control treatment showed the lowest HI (26.98%) in this experiment. The HI indicates the proportion of dry matter allocated to the grain from leaves and stems (Solanki, 2009). Similar results were also reported by Singh *et al.* (2012). Berkesia *et al.* (2018); Yadav *et al.* (2020) also did not find any significant change in the HI of the barley crop when higher N levels (60, 675 & 90 kg N ha^{-1}) were applied.

Data on the cost of cultivation, gross returns, net returns, and B:C ratio under different levels of N treatments are presented in Table 3. Analysis of the data revealed that the cost of cultivation increased with each successive increase in N level from 0 to 90 kg ha^{-1}. Gross and net returns were higher with the application of 30, 45, 60, 75, and 90 kg N ha^{-1} compared to the control treatment. The plot receiving 90 kg N ha^{-1} produced the highest net return (₹31332 ha^{-1}) while the control plot produced the lowest net return (₹10804 ha^{-1}). The highest and lowest B:C ratios were recorded from 90 kg N ha^{-1} (2.10) and control (1.43) treatments, respectively which might be due to the higher HI and lower cost of cultivation recorded in this study. Chakrawarti and Kushwaha (2006); Neetarani *et al.* (2018); Yadav *et al.* (2020) also reported similar findings.

Table 1: Effect of N levels on plant height and number of tillers of the barley crop.

Treatments	Plant height (cm)			No. of tillers per metre row length	
	30 DAS	60 DAS	90 DAS	60 DAS	90 DAS
Control	28.94	50.70	87.34	36.75	51.00
30 kg N ha^{-1}	30.98	51.50	89.69	47.50	58.75
45 kg N ha^{-1}	33.29	62.80	109.9	57.00	59.00
60 kg N ha^{-1}	40.41	66.20	116.7	65.75	84.50
75 kg N ha^{-1}	37.09	59.60	107.1	62.00	77.25
90 kg N ha^{-1}	33.51	48.40	106.1	61.50	75.00
SEm (±)	1.19	2.15	6.26	1.97	2.41
CD (P=0.05)	3.50	6.28	18.31	5.76	7.04

*DAS = Days after sowing

Table 2: Effect of N levels on chlorophyll content and dry matter accumulation in barley crop.

Treatments	Chlorophyll content (SPAD readings)			Dry matter accumulation (g) per plant		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Control	21.77	31.02	31.95	3.75	36.70	71.00
30 kg N ha^{-1}	30.35	35.65	38.64	4.07	34.25	82.25
45 kg N ha^{-1}	45.43	40.87	42.45	4.58	48.25	98.25
60 kg N ha^{-1}	51.54	52.22	51.67	5.93	75.50	115.3
75 kg N ha^{-1}	47.99	49.01	48.93	5.43	55.50	91.75
90 kg N ha^{-1}	46.71	45.86	45.42	5.28	51.50	93.25
SEm (±)	1.50	1.70	1.55	0.17	3.30	6.14
CD (P=0.05)	4.39	4.97	4.54	0.51	9.64	17.98

*DAS = Days after sowing

Table 3: Effect of N levels on harvest index and economics of barley crop.

Treatments	Harvest Index (%)	Economics			
		Cost of cultivation (₹ per ha)	Gross returns (₹ per ha)	Net returns (₹ per ha)	B:C ratio
Control	26.98	25388	36192	10804	1.43
30 kg N ha^{-1}	28.69	26711	44078	17367	1.65
45 kg N ha^{-1}	29.24	27164	50468	23304	1.86
60 kg N ha^{-1}	34.36	27616	54644	27028	1.98
75 kg N ha^{-1}	33.04	28068	55739	27671	1.99
90 kg N ha^{-1}	33.15	28513	59845	31332	2.10
SEm (±)	1.09	-	-	-	-
CD (P=0.05)	3.19	-	-	-	-

CONCLUSIONS

The application of higher levels of N significantly influenced the growth parameters and HI of barley crops, ultimately impacting their economic viability. The study concluded that the optimal N dose for barley growth and HI was 60 kg N ha^{-1}. The treatment with 90 kg N ha^{-1} recorded the highest net income and B:C ratio, making it a recommended option for farmers to improve their productivity and profitability in barley.

FUTURE SCOPE

Nitrogen is an important primary nutrient which is necessary for barley. It is important to note that these findings were based on a single-season crop growth study, and additional experiments over multiple years may be necessary to confirm these results. Moreover, research on split doses of nitrogen in barley needs to be conducted in future to minimize the nitrogen loss and increase the nitrogen use efficiency without compromising the yield and profitability.

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